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LANDUSE – WATER QUALITY MODELLING: A CASE STUDY

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ABSTRACT

There can be no doubt that landuse profoundly affects the quality of water in streams, rivers, lakes and shallow aquifers. However, the task of finding specific cause – effect relationships between different landuses and Water Quality (WQ) is one of the most important ecological challenges of out times. At the present time, few tested procedures are available to study the landuse and Non-Point Source (NPS) pollution impacts on WQ. One methodology which offers considerable promise is the use of statistical analysis of landuse and WQ data from selected regions. Facilitating the systematic application of statistical procedures, in the present investigation, regression equations have been developed between landuse and WQ parameters. The results of the study indicated that landuse can account for up to 45% of the observed variation in mean nitrates, 39% of the observed variation in mean phosphates, 58% of the observed variation in mean fluoride concentration, 46% of the observed variation in mean COD concentrations and 72% of the observed variation in mean potassium concentrations.

KEYWORDS

Non-point source pollution; regression analysis; urban stormwater; water pollution; water quality management.

INTRODUCTION

Landuse and WQ are inseparable. Almost every activity carried out on the land surface affects WQ in one way or another. But, it is seldom easy to find out the relationship between landuse and WQ for several reasons: first, water courses usually assimilate materials from widely dispersed landuses; second, land areas drained by a common waterway nearly always have mixed uses; third, soil supporting given landuse varies significantly in properties affecting infiltration, chemistry, the quality of drainage flows, etc., and fourth, movements of materials from land areas to waterways vary greatly with time and local precipitation pattern.

An assessment of NPS pollution has to some extent been over-shadowed by the urgent need for the treatment of domestic and industrial waste water, consequently, NPS pollution has not been adequately studied and its role in water pollution is poorly understood. It is becoming increasingly evident that to establish the goals of the WQ management programme, regulating and controlling only point sources is not sufficient.

One method of landuse – water quality study follows a natural progression from the foregoing: a detailed consideration of basic WQ phenomena is largely abandoned in favour of more emphasis on comparative analysis. The trade-off can be worthwhile, however, since a large number of watersheds can be included, and quantitative analysis using statistical techniques can be employed.

Stepwise multiple regression is used to explore the relationship between WQ and landuse economic, demographic and geographic parameters within small urban watersheds. Depending on the forms of regression used, up to 90% of variation of WQ parameters was explained by the regression. One of the most detailed studies of WQ and landuse has been Shannon and Brezonik's (1972) investigation of the eutrophication in Florida lakes. More than 80% of the variation of a derived "trophic state indicator" was explained by multiple regression on seven landuse characteristics. These studies have, in general, demonstrated the usefulness of correlation and regression techniques in the analysis of WQ and watershed characteristics.

ABOUT THE STUDY AREA

Warangal town, a District headquarters in Andhra Pradesh, is located in South India. It is situated on latitude 18 degrees North and longitude 79 degrees and 35 minutes. Warangal is a popular historic place with magnificent rock temples in the famous 'Chalukya' style, gigantic forts and large reservoirs. Also, the town falls on the Krishna–Godavari divide with an annual normal rainfall of about 800mm, which occurs during the South-West monsoon period. In addition to the historic importance attached to the town, it has now grown in to an important educational, industrial and commercial centre. Hence, to meet the increased demands of water, the town depends on the summer storage tanks constructed by the ancient rulers.

Badhry tank is one such tank which is used to supplement the water demands of the town, especially during the summer. The catchment area of the lake is of the order of 18.5 sq.km. The catchment of the lake is mainly urban in nature with four widely classified landuses: namely, residential (31.4%), commercial and industrial (22.1%), transportation (12.1%) and agricultural (14.4%). Water from 20 sampling sites located in the different landuses was collected during the study and analysed for water quality parameters, namely, nitrates, phosphates, fluorides, COD and potassium. The study area and the location of the sampling sites are shown in Fig. 1. Applying the step-wise regression techniques, equations were developed between landuse and water quality parameters.

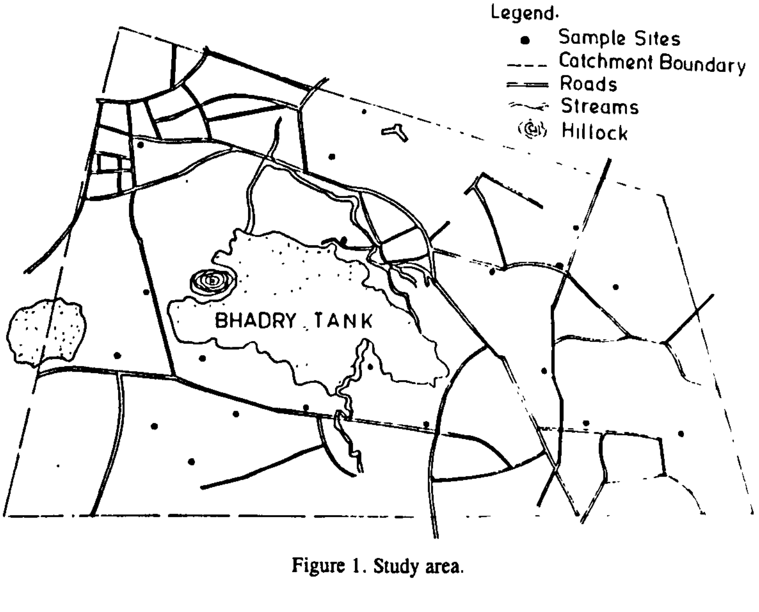

Figure 1. Study area.

RESULTS AND DISCUSSIONS

The variation of the WQ parameters of the lake water with respect to landuse pattern in its catchment can be expressed as:

$$WQ = A * \text{Residential} + B * \text{Commercial} + C * \text{Transportation} + D * \text{Agricultural} + \text{Constant}$$

The coefficients of regression equtions and multiple correlation coefficients obtained by applying step-wise regression techniques between landuse and water quality parameters are given below in Table 1.

Table 1. Coefficients of regression equations and multiple correlation coefficients

Parameter	Coefficients of Equations for landuses				Constant	Multiple cor. coefficient
	A	B	C	D		
Nitrates	+ 13.30	0	-26.21	+ 38.80	+ 4.75	0.44
Phosphates	+ 0.36	0	+ 1.72	+ 1.03	+ 0.16	0.39
Flourides	- 0.77	0	- 2.69	+ 1.76	+ 1.56	0.58
COD	+252.40	+770.60	0	+848.90	+53.54	0.46
Potassium	+122.85	+ 43.50	0	+ 70.30	-34.48	0.72

Nitrates: The equation explains 44% of observed nitrates variation with residential area and agricultural area accounting for 7% and 31% variations respectively and transportation landuse for the remaining 6%. From the above table it can be inferred that the nitrate is 43.55mg/l, if the catchment is 100% agricultural. The agricultural landuse can contribute to the nitrate levels by means of run-off from areas which are cropped, fertilised and manured or a combination of all the three.

Phosphates: The above table explains 38.9% of phosphates variation with residential landuse accounting for 17.8%, agricultural landuse accounting for 5.5% and transportation landuse accounting for 16.6%. Commercial landuse did not enter the table as it could not significantly improve the variation explained. In the catchment, the phosphates concentration is 0.23mg/l, if the total area is residential. This may be due to the contribution of phosphates by domestic waste water.

Fluorides: The results explain 58% of observed fluorides vcariation, with negative regression coefficient except for agricultural landuse, which indicates that as landuse area increases the fluorides concentration decreases. Residential and transportation landuses accounting for negative variation of 7.9% and 37.5% respectively, residential areas account for 12.4% variation of observed levels. Industrial wastes and soils with fluoride compounds are the contributors to the fluoride levels in the lake water. However, the negative correlation can not be clearly explained with available data.

Chemical Oxygen Demand (COD): The coefficients in the table explain 46% of observed COD variations with residential, commercial and agricultural landuses accounting for 17.3%, 21% and 7.5% respectively. The waste water from industrial and commercial areas of the catchment is the main contributor to the COD levels in the lake water.

Potassium: The results explain 72.0% of observed potassium variations, with residential, commercial and agricultural landuses accounting for 67.0%, 2% and 2% respectively. In the catchment residential areas are the main contributors to the potassium levels in the lake water.

CONCLUSIONS

Water quality management should include provisions for the control of water pollution associated with landuse and non-point sources. Statistical procedures, such as regression analysis, provide a methodology for including landuse and NPS considerations in water quality management of watersheds. Application of such techniques to the Badhry catchment in Warangal town has indicated the impact on the concentrations of nitrates, phosphates, fluorides, COD and potassium in lake water. Residential areas had the major impact on phosphates and potassium levels while agricultural areas had impact on nitrates. Commercial landuse affected COD levels of a lake water. However, the relative magnitudes of point and non-point sources could not be estimated from the water quality data collected in the present study.

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